Radiation hazards and protection against them

The X-rays and gamma rays used in radiography, CT and nuclear medicine are examples of ionising radiation. As the name implies, when they interact with matter, they are capable of knocking bits off neutral atoms, leaving them with a net electrical charge.

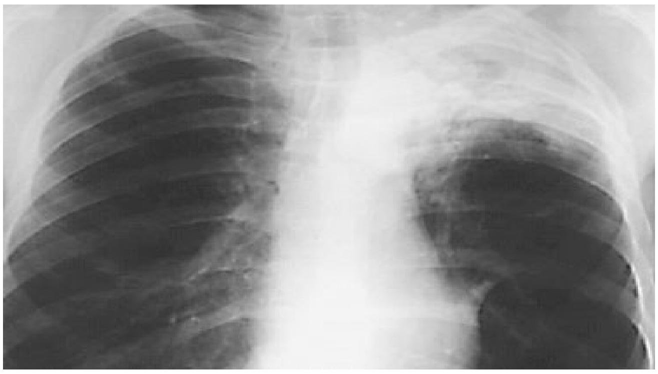
so what?

The interaction which matters biologically is that between the radiation and the nucleic acid in the nuclei of cells. The DNA (deoxyribonucleic acid) is the familiar double helix molecule of Crick & Watson which forms the genetic material of the cell. It is arranged into chromosomes (46 per cell) carrying the genes which code for the structural and biologically active proteins which make us what we are.

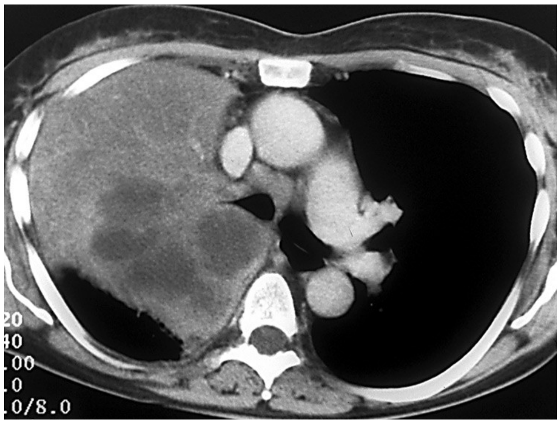
If cells are exposed to high enough doses of radiation, they will be killed. This is the basis of the use of radiation to treat cancer (radiotherapy). When smaller doses of radiation interact with DNA, the result can be subtle or not so subtle changes in one or more genes, producing mutations, but stopping short of killing the cell. How damaging this is will depend on which gene is altered, and whether it is altered enough to produce a protein which no longer does the job it was intended for. Ironically, although high dose radiation can be used to *treat* cancer, the most important effect of the low doses used in diagnostic imaging is the *induction* of tumours in the irradiated tissue.

radiation and cancer

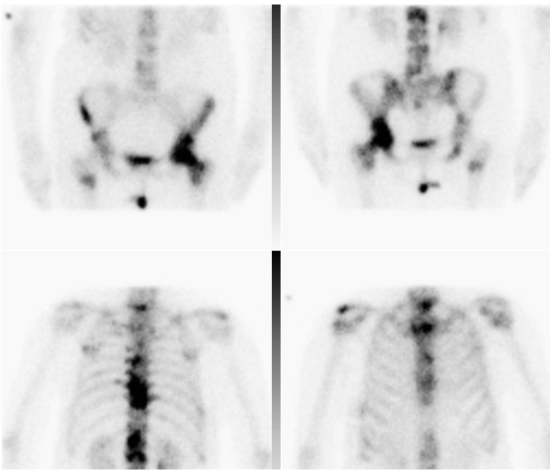
The exact way in which radiation causes cancer is beyond the scope of this website (and the understanding of its author). However, what seems to happen is that occasionally a mutation occurs in one of the many genes that have a regulatory effect on cell growth and division. The end result is a clone (line of cells arising from the division of a single precursor) of cells which divide in an uncontrolled fashion, and which lack the normal inhibitory mechanisms which prevent cells from infiltrating surrounding tissue. This tumour then grows and invades locally, and can spread to distant sites (metastasise) by way of the bloodstream or lymphatic system (see illustrations, below).



chest x-ray, showing lung cancer at the left apex



CT scan showing multiple metastases from the lung cancer



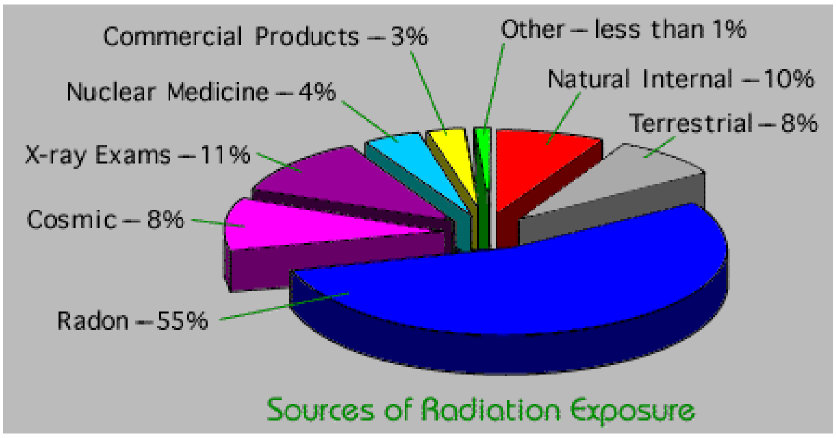
bone scan, showing widespread bone metastases from the lung primary

sources of exposure

It's easy to get caught up in discussions about the hazards of man-made radiation, medical sources in particular, and to forget that we are all being continuously exposed to radiation. The largest single component of this background radiation is radon gas arising from the rocks and soil beneath our feet, and often building up to quite high levels inside buildings. Other contributions come from cosmic rays and other natural emitters in the rocks and soil. The average annual dose from these natural sources is around 2.5mSv, about the same as the dose from x-ray examination of the lumbar spine.

So why worry too much about the doses from diagnostic radiology? Well, although they only account for about 15% of the total dose received per year, medical uses constitute by far the biggest contribution to man-made (and therefore potentially avoidable) sources of radiation.

The pie chart below illustrates this. As an aside, note that the doses from all commercial sources, including nuclear reprocessing plants like Sellafield in the UK, are in the green 'other' category, i.e. less than one percent of our annual exposure. This might come as a surprise, given the amount of media coverage generated by the emotive topic of nuclear waste discharges, and the numerous pressure groups clamouring for more expenditure to reduce the perceived hazard. A far more efficient dose-reduction measure would be to invest in providing our radiology departments with modern equipment. This is another example of the failure of the public (and the press and politicians) to take a logical view of risk assessment (see below, in 'communicating the risk).



just how dangerous *is* radiation in diagnostic doses?

The simple answer is that we don't know.

because:

- the harmful effect we are looking for is very common in the population – approximately 1:3 of us will develop cancer at some stage in our lives
- although we don't know the exact size of the risk from diagnostic doses, we know it is very small, so it will never be possible to detect the additional few cancers caused by diagnostic irradiation against the high background level of 25-30%
- it is not possible to differentiate a cancer caused by radiation from one that would have occurred anyway
- the cancer will often not appear until many years after the exposure that did the damage

So, we assume the worst. Because, in theory, a single photon of ionising radiation could induce a critical mutation, the assumption is made that there is no threshold dose below which harmful effects cease to occur. And because we can't measure the effects of low doses directly, the known effects of high doses are extrapolated downwards, assuming a more or less straight-line relationship between size of dose and the magnitude of the effect.

communicating the risk to patients

How much information we should give to patients is a hot topic, and increasingly, the answer is 'all of it'. We are rapidly approaching the situation which obtains in the USA, where patients have to be informed of *all* the conceivable risks of any procedure or treatment, no matter how remote. Any attempt by doctors or other health care professionals to limit the information given is now seen as 'arrogant' or 'paternalistic'.

But it's not easy to communicate risk levels to patients in terms that are meaningful to them, and this is related to the complicated area of risk perception.

How we perceive risk:

We are not very logical in our response to risk. This is largely because our perception and rating of relative risks is coloured by a number of factors (Covello and Merkhofer, 1994):

- catastrophic potential – people are more concerned about fatalities and injuries that are grouped in time and space (aeroplane crashes) than about fatalities and injuries that are scattered or random in time and space (car accidents);
- familiarity – people are more concerned about unfamiliar risks (ozone depletion) than familiar risks (household accidents);
- understanding – people are more concerned about poorly understood activities (exposure to radiation) than those that may be understood (slipping on ice);
- scientific uncertainty – people are more concerned about risks that are scientifically unknown or uncertain (genetically modified food) than risks well known to science (car crashes);
- controllability – people are more concerned about risks not under personal control (pesticides on food) than those under personal control (driving a car);
- voluntary/involuntary – people are more concerned about risks that are imposed (residues in food) rather than voluntarily accepted (smoking cigarettes);
- dread – people are more concerned about risks that have dread results (Creutzfeldt-Jakob disease);
- institutional trust – the days when people would trust doctors/food manufacturers/the government to look after their interests are long gone, and this distrust can colour their perception of risk

Question:

Using the information above, explain why it is that a patient who is a heavy smoker, and has developed lung cancer as a result, can still claim to be worried about the adverse effects of the radiation used for the CT scan used in staging his tumour.

answer:

the smoking risk is one which he took on voluntarily, and is therefore under his own control. He also feels that he understands the risk from cigarettes, which is a familiar one.

Radiation is an unknown quantity, and is something which invokes dread in the public. Also, it is being forced on him, and therefore out of his control. We are also asking him to trust someone else (I.e. The medical staff) not to give him a dangerous dose of radiation.

but it's not all <u>bad</u> news!

In all of this, we have been concentrating on the *risks* of radiation. There has so far been no consideration of the *benefits* of making a diagnosis and giving the patient the appropriate treatment. When explaining risks to patients, they must therefore be put in the appropriate context. We should only subject patients to ionising radiation if the likely benefits to their health outweigh any small risk. This is the basis of the *justification* of medical exposures; a concept which is at the heart of the legislation governing our use of radiation in medicine. In other words, if the radiation professionals do their job peoperly, patients will only be subjected to radiation where the benefits outweigh the risks.

could low-dose radiation actually be <u>good</u> for you?

A slightly subversive suggestion you might think, but there is actually quite a body of evidence indicating a possible protective effect of low doses of radiation. This concept is known as **radiation hormesis**, and its proponents put their ideas forward with almost religious zeal, as do those who think they are dangerous lunatics. As well as basic research showing the possible mechanism for such an effect (which includes deactivation of free radicals and stimulation of DNA repair mechanisms) there are several population studies apparently confirming the protective effect. One of these is a 100 year retrospective and prospective study of the health of British radiologists carried out by Sir Richard Doll and his team of epidemiologists at Oxford (the same team that first alerted us to the risks of smoking in the fifties and sixties). It turns out that radiologists have a significantly lower cancer and all-causes mortality rate than other doctors. The other large investigation quoted in this context is the nuclear shipyard worker study, and both of these are mentioned in the following link to paper by John Cameron, one of the more enthusiastic proponents of hormesis:

http://bjr.birjournals.org/cgi/content/full/78/925/11 and this is a recent addition to the blogosphere which gives some background and plenty of further links for those interested in the concept of hormesis:

http://www.coherentspace.info/radiation-hormesis/index.html

the bottom line

Just in case that last section confused you, the jury is still out concerning the effects of low-dose radiation, so we still seek to keep exposure of patients to a minimum by applying the ALARP (as low as reasonably practicable) principle. And in any case, in these days of multi-slice CT scanning it is quite possible to exceed the doses that even the most enthusiastic proponent of hormesis would consider beneficial.